

Solution to the unavailability of old cars' emission values for the purpose of an environmental road tax base

Petr DAVID^{a*}, Milan KŘÁPEK^b

^a *Department of Accounting and Taxes, Faculty of Business and Economics, Mendel University in Brno, Zemědělská 1, 61300 Brno, Czech Republic.*

^b *Department of Mathematics, Statistics and Informatics, Private College of Economic Studies Znojmo, Loucká 656/21, 669 02 Znojmo, Czech Republic.*

Abstract

The article deals with the issue of the assessment of emission values of personal road motor vehicles that are usable for the introduction or change of an environmental road tax base. It searches for options for theoretical emission assessment in the case of unavailability of this figure to avoid the duality and consequent deformation of the existing or introduced road tax. During the calculation of the particulate emission value of old diesel and petrol engine vehicles, it is advisable to include only the available figures for the engine capacity and the year of initial registration of the car make and type. Including the square-root relationship between engine capacity and emissions corresponds better to reality, improving the results. The application of these processes leads to the formulation of equations enabling the determination of unknown emission values of vehicles registered since 2000, which describe these vehicles' production of emissions quite accurately. Including the frequency of vehicle registration in the model proved to be unsuitable; therefore, the model is applicable in general.

Keywords

Environmental tax, personal vehicle, emission, carbon dioxide.

JEL Classification: H21, H23

* david@mendelu.cz (corresponding author)

The paper was processed with financial support from the project EE2.3.30.0031 *Postdoc Contracts at MENDELU Technical and Economic Research*.

Solution to the unavailability of old cars' emission values for the purpose of an environmental road tax base

Petr DAVID, Milan KŘÁPEK

1. Introduction

Since the end of the 1990s, the EU has been trying to fulfil the liabilities introduced by the Kyoto Protocol (European Commission, 1997), which advocates the reduction of the average emissions of new vehicles. To achieve this goal, the EU has devised a strategy that consists of three pillars and includes both the supply party (consensual agreements with car manufacturers) and the demand party, which focuses on consumer awareness and taxation measures. In 2005, the European Commission put forward a proposal for a directive, COM/2005/261, which deals with personal vehicle taxation. One of its main points is calculating the annual road tax on the basis of carbon dioxide emissions in g/km. One of the directives included in the above-mentioned proposal was the removal of registration tax. The European Union concluded at the beginning of the last decade that various taxation forms applied to motor vehicles at their purchase in individual European Union states prevent the movement of motor vehicles in the united market; what is more, they prevent this field from profiting from economies of scale and violate competitiveness. Therefore, it was suggested that this tax should be removed gradually and replaced with an annual road tax. However, this directive has not been passed and no other similar instrument has come into force. Notwithstanding, none of the existing tax systems – annual road tax, consumption tax on mineral oils and registration tax – can be considered a perfect system of paying for harmful consumption or using motor vehicles (David, 2012a). The EU member countries, including the Czech Republic, are therefore still not obliged to impose and enforce taxation based on carbon dioxide emissions.

However, the Czech Republic, as well as other EU countries, should deal with road motor vehicle taxation according to emission values, taking into consideration the social demand for high quality of the environment. It is certain that addressing the issue of emissions on the national level is completely inadequate. Ramanathan and Feng (2009) state that air pollution cannot be considered an urban or local problem; it is a problem spanning countries and even continents. The method of taxation or a change in the method of taxation of motor

vehicles does not necessarily affect the selection from these taxes, as confirmed by England and Carlson (2008). On the other hand, it is desirable to create an additional tax burden, provided that the amount of the current taxation does not correspond to the social cost of motor vehicles. This can provide a neutral model for the taxation of motor vehicles. The total additional burden will, according to Auerbach and Feldstein (2002), depend on the actual amount of tax and the cross-elasticity of demand.

To calculate the road tax of vehicles first registered in 2000, it is not possible to use the current system of taxation, as in the UK. Indeed, it results in the duality of motor vehicle taxation, uncertainty about the fairness of the system and distrust of taxpayers, including a lack of awareness regarding the need for taxation. We will therefore, in addition to explaining the greatest share of emission values through the variables mentioned, examine the relationships of the emission details with the engine capacity, fuel type, vehicle brand, vehicle age and frequency of vehicle registration in the Czech Republic. The objective of the study is to formulate a suitable and generally applicable proposal for a tax policy considering the emissions of personal vehicles on the basis of identifying a calculation mechanism for the emission values of personal vehicles should this figure not be recorded in the vehicle register.

It is necessary to work with data on CO₂ for vehicles registered in the Czech Republic to determine the environmental tax base levied on personal vehicles according to CO₂. Unfortunately, the Motor Vehicle Register of the Czech Republic does not provide this information on vehicles registered in the country.

Because the system of taxation according to CO₂ exists in several European countries, there are databases that contain vehicles registered in a particular country and data on CO₂ for these vehicles. Therefore, it is necessary to use two databases: the Vehicle Database, in which information on all the vehicles registered in the Czech Republic can be found, and another European country database, in which we can find the vehicles registered in another member state, including emission data suitable for electronic processing. The database of Czech vehicles was

obtained from the Central Vehicle Register, which was managed by the Ministry of Interior until July 2012 (MoI, 2012).

The database containing CO₂ details for particular vehicles is available in individual EU countries that calculate taxation according to CO₂ values. The United Kingdom's database is publicly available and is the only one that includes the data since 2000, thus providing the oldest data (VCA, 2012). Therefore, this database was used. It is possible to allocate the emission values from the VCA database to vehicles registered after 1999 in the Czech Republic according to the individual makes and types of vehicles. Further characteristics available are the fuel type, engine capacity stated in cubic centimetres, registration frequency of the particular vehicle type in the Czech Republic and year of the initial vehicle registration. The results of the examination of the dependence of the age of the vehicles and their emissions are indisputable. The examination was conducted by Singer and Harley (1996), when almost two-thirds of the emissions of rolling stock were produced by vehicles aged over ten years. The need to differentiate our calculation by fuel type confirms the study by the USEPA (2005). The fuel type is one of the primary determinants of carbon dioxide emissions. Consequently, the above-mentioned characteristics can be used for emission value quantification of vehicles registered before 2000.

Within the frame of the sample of vehicles registered from 2000 to 2012 in the Czech Republic, a correlation analysis with the aim of creating a correlation matrix will be employed and, consequently, the dependence of random variables will be determined (fuel type, engine capacity stated in cubic centimetres, registration frequency of the particular vehicle type in the Czech Republic and year of the initial vehicle registration) to maximize the level of explanation of CO₂ emissions. With these data and using the statistics software Statistica 9.0, a suitable model for the regression analysis will be determined.

The results of the regression analysis will be equations for the calculation of the CO₂ emission volume, which will enable the calculation of emissions in the case of vehicles for which the emission volume is not available. This allows us to combine the databases including a suitable (not deforming and without duality) road tax base as declared or calculated emission values of every operating personal vehicle.

2. Theory of environmental taxation of vehicles

In theory, dealing with externalities in vehicular traffic is simple and it is known as the so-called Pigouvian tax. It is a corrective tax and its primary merit is the feasibility of imposing a tax that is equivalent to the

costs of the society on the negative externality producer (Holman et al., 1999). Santos et al. (2010) mention environmental pollution, accidents, traffic congestion and dependence on oil as the externalities of road traffic that are not factored into the market prices. These costs, which encumber the society, are not taken into consideration and nobody pays for them; they are not reflected in the prices of products and services. The assessment of a society's costs of using motor vehicles is very complicated, if not impossible. Nevertheless, Cnossen (2005) states that it is possible to quantify significant externalities in this field and less significant impacts can be left out. The reason why CO₂ emissions should play such an important role is obvious from the Ministry of Transport's (2011) statistics, according to which individual car transport is responsible for 53.7% of the production of this polluting substance in transport. In this situation, the road tax can be used to remedy negative externalities, thus providing economic efficiency in the case of the violation of Pareto-efficient allocation of resources (David, 2012).

Introducing the above-mentioned factor into the tax system would lead minimally to partial elimination of the externalities produced by road transport or to the collection of funds to reduce their effect. Proost et al. (2009) do not observe a dramatic drop in traffic volume after introducing a tax based on emissions caused by operating personal vehicles. However, Johansson et al. (2009) did notice a decrease in road traffic volume after imposing a higher road tax during an experiment carried out in Stockholm. Nonetheless, the result can be interpreted as being influenced by the local character of the experiment and by a reduction of the excessiveness caused by the original inefficient allocation. The following study offers more possibilities for generalization. According to the Low Carbon Vehicle Partnership (2011), the number of vehicles with low CO₂ emissions in the UK in 2010 doubled to more than 57 thousand compared with 2009. These cars are classified as being subject to the lowest road tax rate. The average CO₂ emissions of all new personal vehicles registered in 2010 decreased to 144.2 g/km, which represents a drop of 4% from the 2009 level. This fact is evidence of the continuing trend of reducing the average emissions of newly registered cars after introducing a taxation system based on emissions.

We can often see propositions to solve the given situation that deform the market, for example in Sergeant et al. (2008), who suggest applying or increasing fees for parking, passing through or driving into selected localities with respect to reducing air pollution. At the same time, these authors offer a much better alternative in the form of providing high-quality, more eco-friendly optional means of transport for both people and merchandise, which should, however, rather be considered a suitable complement to a correctly

designed motor vehicle operation tax. Murray (2011) shows in his presentation how the number of emission zones and the road tax rates have risen since the incorporation of CO₂ emissions into taxation in the UK. It is apparent that the system based on bands or degrees causes injustice and distortion. In spite of that, the road tax system in the UK has remained based on degrees with all the negative impacts that entails.

None of the taxation systems implemented to date, that is, the annual road tax, mineral oil consumption tax or registration tax, can be regarded as a perfect system of paying for harmful usage, namely operating road motor vehicles. This is true also for the system applied in the UK due to progressive rates and its validity for vehicles registered since the year 2000. If we disregard aspects other than the emission effects of vehicle operation, such as infrastructure wear, noise or accidents, theoretical options for optimal road motor vehicle taxation exist. The real emissions are considerably influenced by such factors as the motor vehicle type, motor vehicle weight, speed, fuel, engine adjustment, catalytic convertor effectiveness, age of the motor vehicle and its maintenance, air temperature, road condition, terrain and road maintenance (Adamec, 2005). An attempt to measure the actual emissions would require a highly sophisticated and technologically advanced system (Borger and Mayeres, 2007). The volume of actually produced emissions could be measured using an emission gauge in every motor vehicle. The technology that would be used for this system would have to meet requirements regarding cost-effectiveness, reliability, misuse resistance and personal data protection (Santos et al., 2010). However, this method appears to be excessively costly and particularly liable to tax evasion.

It is therefore necessary to acknowledge that the system of annual road tax using the declared emissions produced per kilometre is currently the most feasible alternative to tax the harmful effects of road motor vehicle operation as concerns emissions. On the other hand, the annual road tax allows for neither the actual distance travelled nor the specific conditions and state of the vehicle to be considered and thus has absolutely no information value regarding the actual emissions produced. Including the emissions of the respective car's make and type according to its technical documentation does not deal with the actual emission volume in relation to the extent of vehicle use. Regardless, Blanc and Derkenne's study (2010) proves the effect of the overall reduction of the emissions produced. As the possible practicable form of the environmental tax base, it is identified using the declared emissions of the given car make and type declared in its technical documentation, and though it has its drawbacks, it also has a clear environmental character. The problem is that the emissions of older

vehicles are not recorded in their technical documentation.

3. Creation of the model identifying the emissions of older vehicles

Annual passenger motor vehicle taxation is a tool that is frequently used in the majority of European Union member countries. Property tax applied to motor vehicles is further differentiated into tax applied to passenger motor vehicles and tax applied to motor vehicles used for business purposes. Andrlík (2013) points out that currently, concerning personal vehicles in the Czech Republic, it is precisely subjecting solely vehicles used for entrepreneurial activities to this tax that prevents the collection revenue from being higher, as the number of registered personal cars is increasing.

Applying road tax in the Czech Republic, as we know it today, dates back to when the new tax system, protected by Law no. 16/1993 Coll. on the tax system from 1 January 1993, was established (Czech Republic, 1993). The road tax in the Czech Republic does not, in fact, reflect an effort to compensate for polluting the environment, which is also validated by the UK's finance ministry (HM Treasury), which deems the tax rate based on carbon dioxide emissions to be a more reliable way of measuring the impact on the environment as opposed to the tax rate based on the displacement of the engine expressed in cm³ (HM Treasury, 1998). The operation of motor vehicles is further burdened by excise duties on mineral oils and the standard rate of value-added tax. These taxes represent well a significant emission factor, the fuel consumption, which we are unable to take into account when calculating the emissions of older vehicles due to the absence of the necessary data.

There are in total 1,862,926 personal vehicles registered in the Czech Republic and involved in our research, of which 1,054,819 are equipped with gasoline engines and 808,107 are powered by diesel engines. Altogether there are 2,164 types of vehicles with a petrol engine and 1,025 types with diesel engines. Now we can determine the correlation matrix of the variables engine capacity, fuel consumption, year and emissions.

The best possible indicator for quantifying emissions is the consumption of a particular make and type of motor vehicle. These data are, however, not provided for older motor vehicles, as mentioned above. The data available on motor vehicles registered before 2000 indicate that we will be forced to use only the engine capacity and the year of the initial vehicle registration as this alternative. The correlation matrix in Table 1 shows that the emissions are strongly determined by the engine capacity, which is why this

value will primarily serve as the basis for estimating emissions. The correlation results indicate strong dependence between emissions and engine capacity. Therefore, we will conduct a regression analysis and, with its help, obtain the parameters of the regression line. When based on the known engine capacity, such regression line estimates correspond to CO₂ emissions. The calculation will include all the vehicles registered in the Czech Republic in the period 2000 to 2012.

When carrying out a linear regression for 1,054,819 vehicles with petrol engines and all vehicles with diesel engines, which is 808,107 vehicles in the period, we obtain the following results, presented in Table 2.

Table 2 Results of the linear regression to estimate the CO₂ based on the engine capacity

	Gasoline engines		Diesel engines	
	R = 0.857 R ² = 0.734		R = 0.789 R ² = 0.623	
	b	std. error of b	b	std. error of b
Constant	73.580	0.054	29.318	0.110
Engine capacity	0.061	0.000	0.066	0.000

The calculation of the gasoline engine regression produces the equation

$$\text{CO}_2 = 73.580 + 0.062 \cdot \text{Engine capacity}$$

which explains the relationship between the engine capacity and the amount of CO₂ emissions for 73.4% of cases. The remaining variance is to be attributed to factors other than those available and included in the study.

The result of the diesel engine regression produces the equation

$$\text{CO}_2 = 29.318 + 0.066 \cdot \text{Engine capacity}$$

which explains 62.3% of the results of estimating the amount of CO₂ emissions from a known volume of the engine. Both regression curves show that an increase in the engine capacity is associated with an increase in the amount of CO₂ emissions produced, which corresponds

to the original expectations and the results of the conducted correlations.

There is direct dependence between fuel consumption and emissions; however, the same dependence may not apply to the relation between consumption and engine capacity. The large volume of engine performance is often not used to its maximum value and, thus, the consumption is slightly reduced. Doubling the engine capacity, hence, does not lead to doubling the fuel consumption; instead, the fuel consumption will be lower than double. From this finding, we can derive the assumption that the capacity does not affect the engine power linearly. In this respect, a root or logarithm of the engine capacity may be relevant. Because we assume a direct linear relationship between consumption and CO₂ emissions, a square root will be used in estimating the emissions based on the engine capacity in Table 3.

Table 3 Results of the non-linear regression to estimate the CO₂ based on the engine capacity

	Gasoline engines		Diesel engines	
	R = 0.874 R ² = 0.764		R = 0.795 R ² = 0.632	
	b	std. error of b	b	std. error of b
Constant	-44.144	0.113	-111.554	0.227
$\sqrt{\text{Engine capacity}}$	5.473	0.003	6.103	0.005

The resulting equation for calculating the emission levels of personal vehicles with petrol engines using the square root for the relationship between engine capacity and emission values takes the parameters

$$\text{CO}_2 = -44.145 + 5.473 \cdot \sqrt{\text{Engine capacity}}$$

This relationship explains the relation between the engine capacity and the amount of CO₂ emissions in 76.4% of cases, which is an improvement in the explanatory power of 3.0% as compared with the original alternative.

Table 1 Correlation matrix for gasoline and diesel engines

	Correlation matrix for gasoline engines N = 1,054,819					
	Engine capacity	Year	CO ₂	Consumption	Average	Standard deviation
Engine capacity	1.000	-0.076	0.857	0.870	1923.021	305.169
Year	-0.076	1.000	-0.413	-0.162	2005.177	3.707
CO ₂	0.857	-0.413	1.000	0.998	155.338	25.331
Consumption	0.870	-0.162	0.998	1.000	8.773	2.415
	Correlation matrix for diesel engines N = 808,107					
	Engine capacity	Year	CO ₂	Consumption	Average	Standard deviation
Engine capacity	1.000	-0.036	0.789	0.740	1445.160	370.182
Year	-0.036	1.000	-0.162	-0.130	2005.046	3.928
CO ₂	0.789	-0.162	1.000	0.977	162.591	26.604
Consumption	0.740	-0.130	0.977	1.000	6.482	1.545

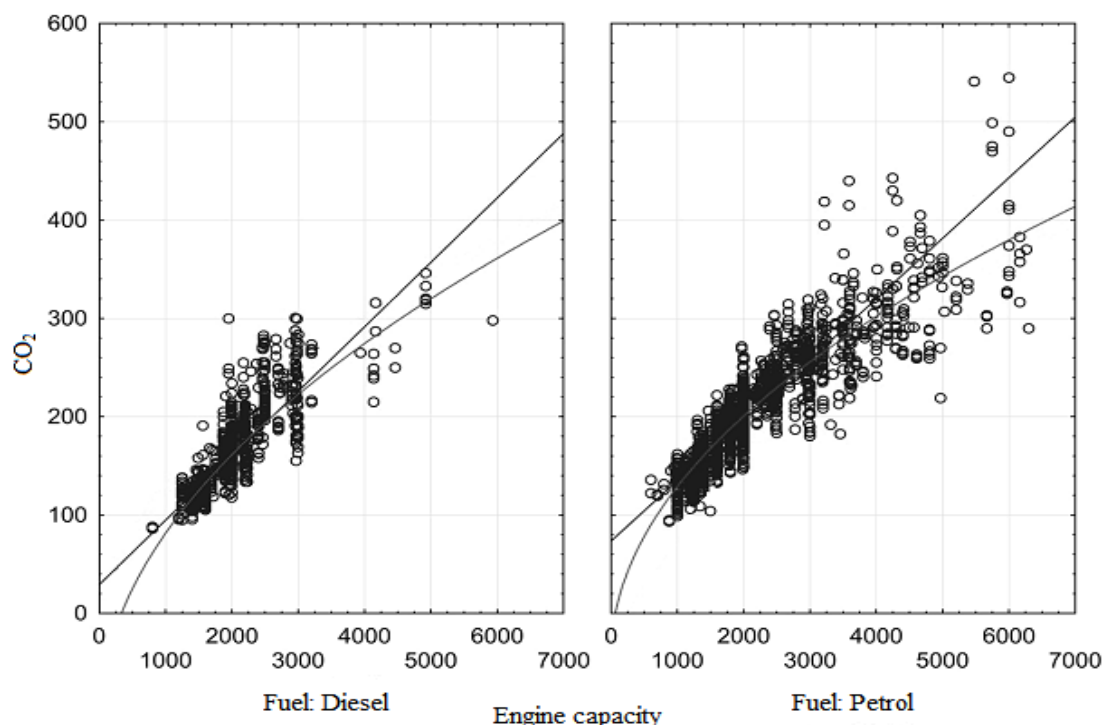


Figure 1 A point diagram of engine capacity–CO₂ with regression curves

Similarly, we obtain an equation for calculating the emission values for diesel vehicles using the square root in terms of the relationship between the engine size and the emissions in the following form:

$$\text{CO}_2 = -111.554 + 6.103 \cdot \sqrt{\text{Engine capacity}}$$

This equation explains the relationship between the engine capacity and the amount of CO₂ emissions in 63.2% of cases, which is in this case an improvement of the original explanatory power, this time by 0.9%.

The considerable increase in the explanatory power of both the equations explaining the emission values based on the engine capacity is an indisputable advantage. Furthermore, these equations better reflect the reality, which, consequently, prevents systematic underestimation or overestimation of the emission values.

It is apparent from Figure 1 that if we considered the relationship between emissions and engine capacity to be direct, then, assuming zero emissions for zero engine capacity, the calculated emissions would favour vehicles equipped with engines of smaller capacity over vehicles with engines of greater capacity. In the following part, we will focus on the optimization of the model using a root for the relation between the emission values and the engine capacity.

The correlation matrices in Table 1 present the fact that the year of production affects the amount of vehicle emissions. Although this effect is not as strong as in the

case of the engine capacity, it is, nonetheless, remarkable. The fact corresponds to the technological and technical progress that follows the trend of decreasing consumption and thereby also decreasing emissions over time. Thus, let us implement the first year of registration (manufacture) of the vehicle type and make in the regression model.

The correlation coefficient between the production and the amount of emissions produced equals -0.162 for diesel engines. For gasoline engines, we can find a higher value of the correlation coefficient of -0.413 . In both cases, however, we can say that newly produced vehicles have less power because the emissions are directly correlated with the consumption of a vehicle.

The regression results of gasoline engines in Table 4 correspond to the equation

$$\text{CO}_2 = 4532.638 - 2.279 \cdot \text{Year} + 5.281 \cdot \sqrt{\text{Engine capacity}}.$$

This equation explains the relation between the capacities of personal vehicles, the age of the vehicles and their emission values in 87.6% of cases. The inclusion of variables reflecting the age of the vehicle has improved the proportion of emissions that can be explained by this regression model by 11.2%.

The resulting equation for estimating the emissions of diesel vehicles in Table 4 is

$$\text{CO}_2 = 1550.407 - 0.828 \cdot \text{Year} + 6.055 \cdot \sqrt{\text{Engine capacity}}.$$

We can see from the results that vehicles with diesel engines are not as influenced by the variable of the year of production as vehicles with engines that run on petrol. This fact indicates a significant difference between the market with vehicles using petrol engines and the one with vehicles using diesel engines. This difference may also be associated with a different approach of customers buying vehicles with petrol and diesel engines.

Table 4 Regression results for the estimation of CO₂ based on the engine capacity and year of registration

	Gasoline engines		Diesel engines	
	R = 0.936 R ² = 0.876		R = 0.804 R ² = 0.647	
	b	std. error of b	b	std. error of b
Constant	4532.638	4.674	1550.407	9.080
Year	-2.279	0.002	-0.828	0.005
√Engine capacity	5.281	0.002	6.055	0.005

Let us now consider the possibility of determining more exact relationships of given characteristics based on sorting vehicles into several categories according to selected characteristics, of which the engine capacity is the most significant available determinant of CO₂ emissions.

We proceed from the overview of the current number of vehicles sorted according to the displacement of petrol engines in Graph 3, which makes it obvious that buyers tend to choose vehicles that are just below the borderline of an engine capacity divisible by 100. Alternatively, it is possible to state that producers make vehicles especially with such an engine capacity. Mostly, this fact is evident in the case of displacement of 1,190 cc–1,200 cc, 1,390 cc–1,400 cc and 1,590 cc–1,600 cc.

The numbers of the kinds of vehicles sold with particular figures of petrol engine capacity are displayed in Figure 2 in narrow columns. Figure 2 also shows the numbers of the kinds of vehicles sold in the Czech Republic, which shows that even car makers adapt to the preferences of buyers who buy vehicles with petrol engines with displacement coming close to a figure divisible by 100.

Figure 3 shows that with diesel engines the tendency to buy vehicles just below the line of engine capacity divisible by 100 is not as apparent as with petrol engines. There are very small differences between the frequencies of engine capacity below a figure divisible by 100 and the frequencies of engine capacity with a figure divisible by 100. In spite of that, in Figure 3 we can see two intervals to which most vehicles registered in the Czech Republic belong: 1,890 cc–1,900 cc and 1,990 cc–2,000 cc.

We can deduce that the reason for the frequencies of vehicles always just below the line of the whole value of 100 is the external conditions, not technological or other internal reasons of car makers. It is evident that when operating a car it is necessary to bear a number of costs, the amount of which depends on the engine capacity of the particular vehicle. These costs, such as third-party insurance or other insurance sums, are determined in intervals. Consequently, it is more cost-saving to possess an engine capacity that is 10 ccm lower and thus pay less for the above-mentioned costs. The market and car production are distorted by this method of determining the sums related to the operation of personal vehicles in intervals. If we do not want to contribute to this distortion, we must not model the environmental road tax in intervals, even in the case of making the calculation of the emission values of vehicles registered before 2000 more accurate. Another reason is the fact that, due to calculation variances, it could lead to a paradoxical situation in which a vehicle with a smaller engine capacity would *ceteris paribus* be burdened by a higher tax than a vehicle with a bigger engine capacity. At first sight, it becomes apparent that the imposition of tax would not be fair here. For the reasons mentioned, let us leave the idea of improving the accuracy of calculating the emissions of old vehicles by sorting them into groups according to the engine capacity and concentrate on other options for finding the best possible way to calculate carbon dioxide emissions.

We will now concentrate on the behaviour of consumers or, more precisely, the buyers of vehicles. If we determine the correlation ratio between the emissions and the year of production with diesel engines without factoring in the number of vehicles bought, only the vehicle types produced in the particular year, we obtain the value of -0.226. However, the ratio changes to -0.162 when factoring in the number of vehicles.

If Table 1 and Table 5 are compared, it is obvious that the correlations with diesel engines fall when factoring in consumer preferences. This can be caused by the fact that buyers of vehicles with diesel engines do not consider the amount of emissions as much, but they prefer to buy lower-cost vehicles with higher emissions. Considering the fact that diesel engines usually have lower fuel consumption than petrol engines, it is no surprise that further improvement to the detriment of the price is not particularly significant for the buyers.

On the other hand, the correlation ratio with petrol engines between the year of production and the emissions of vehicles produced equals -0.239, which approximately corresponds to the value found for diesel

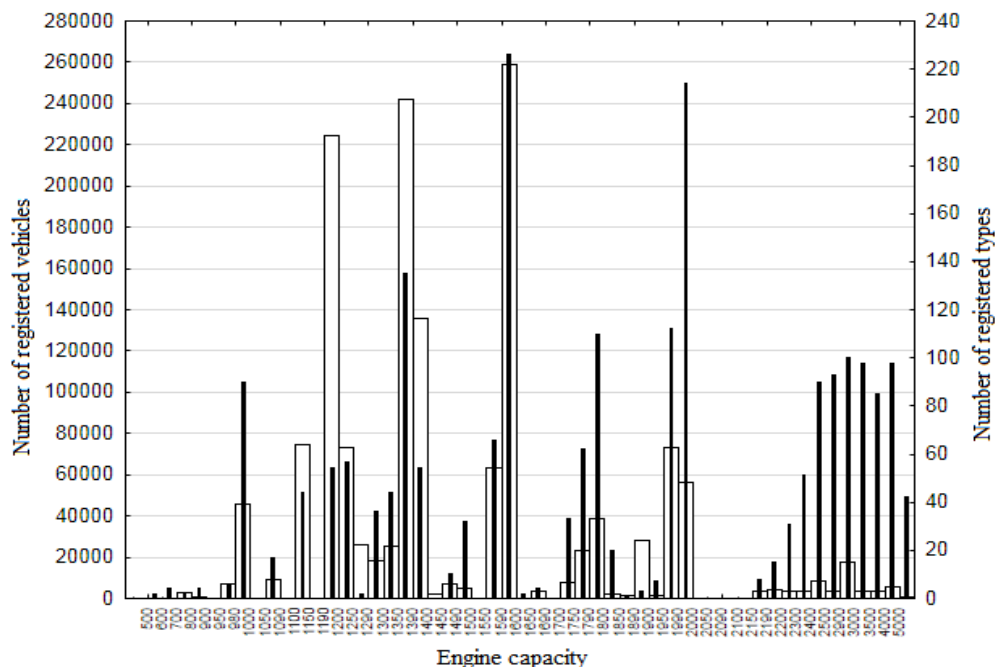


Figure 2 Overview of vehicles with petrol engines

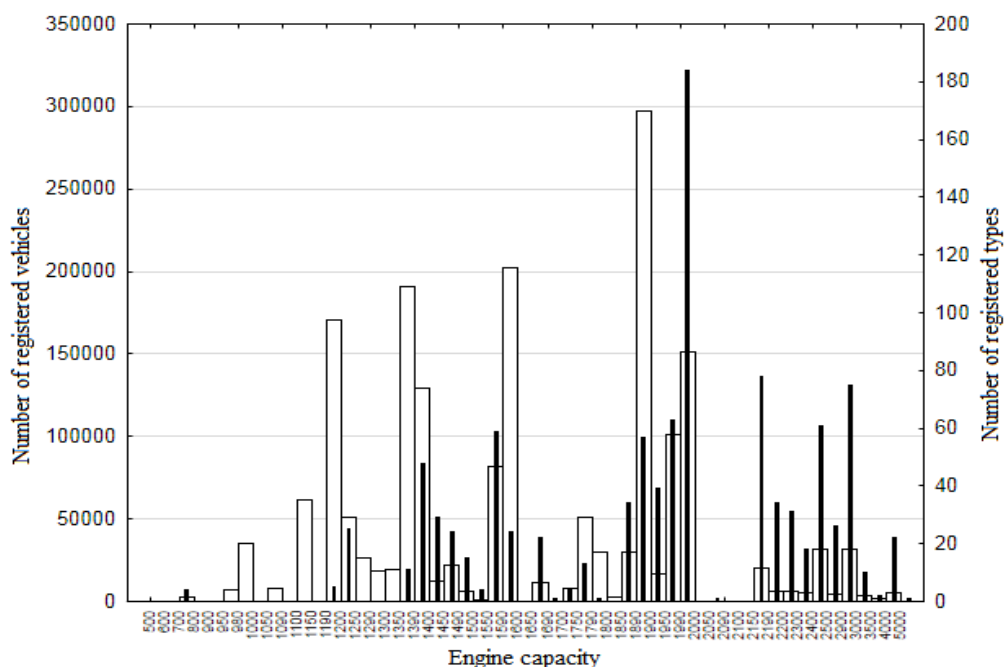


Figure 3 Overview of vehicles with diesel engines

Table 5 Correlation matrix for petrol and diesel engines without factoring in the frequency of vehicles

	Correlation matrix for gasoline engines N = 2 164			Correlation matrix for diesel engines N = 1 025		
	Engine capacity	Year	CO ₂	Engine capacity	Year	CO ₂
Engine capacity	1.000	-0.008	0.894	1.000	-0.066	0.837
Year	-0.008	1.000	-0.239	-0.066	1.000	-0.226
CO ₂	0.894	-0.239	1.000	0.837	-0.226	1.000

engines. Therefore, producers are attempting to improve both types of engines similarly. However, consumers buying vehicles with petrol engines tend to buy vehicles with lower emissions, which is obvious from the correlation ratio of -0.413 in Table 1.

The above-described consumer behaviour leads us to disregard user behaviour, which is often influenced by criteria other than those considered here and which is distorted to a large extent by the current system of vehicle taxation and other costs relating to the ownership and operation of a vehicle. Producers are also influenced by this system, but Graphs 3 and 4 show that this influence is not especially strong. Thus, to estimate the emissions of a vehicle, it is not necessary and probably not appropriate to proceed from the number of vehicles bought.

Let us take into consideration only the different types of produced vehicles operating in the Czech Republic and determine estimates from the data including 2164 types of vehicles with petrol engines and 1025 types of vehicles with diesel engines.

The resulting equation for calculating emission values for vehicle types with petrol engines with the use of the square root relating the engine capacity, age of the vehicle and emissions is as follows according to the results shown in Table 6:

$$\text{CO}_2 = 6729.485 - 3.378 \cdot \text{Year} + 5.547 \cdot \sqrt{\text{Engine capacity}},$$
and in the case of vehicles equipped with diesel engines

$$\text{CO}_2 = 3816.232 - 1.957 \cdot \text{Year} + 6.269 \cdot \sqrt{\text{Engine capacity}}.$$

These results are interesting in several respects. It is obvious that the ratios representing the influence of the engine capacity remain almost unchanged, whereas the ratios determining the influence of the year of production have changed significantly. This means that producers make vehicles with lower consumption more often, but customers do not buy them to the same degree. The probable reason may be the higher price of vehicles with very low fuel consumption.

Another interesting result is the confirmation of the difference between the markets for petrol and diesel engines. In terms of petrol engines, disregarding the variable of the number of vehicles sold led to a decrease in the amount of variances of emissions based on the year of production and engine capacity explained; the

explanatory power decreased by 0.4%, from 87.6% to 87.2%, which is not a significant difference. As for diesel engines, the explanatory power increased by 10.5% from 64.7% to 75.2%, which, on the contrary, is an important change reflecting the difference between the behaviour of producers of diesel engines and the behaviour of vehicle buyers.

4. Conclusion

Introducing taxation on road motor vehicles in the Czech Republic and other EU countries with respect to the environment is strongly advocated. There are serious weaknesses in the current systems of taxation for road motor vehicles. Many countries in the European Union do not consider the environmental aspects of transport in their road taxes or such tax elements play a minor role. In countries where emissions enter into the calculation of the road tax, critical points were ascertained, mainly in the domain of fairness and the distortion effects of the tax application.

The base of the road environmental tax according to the second-best approach, also preferred by Cnossen (2005), should be the amount of emissions produced per item of each realized ride of a vehicle. This figure is available for vehicles registered since 2000. However, it is necessary to deal with older vehicles as well, which is clearly indicated by Singer and Harley (1996). With vehicles registered before 2000, it is possible to calculate the emission value.

The best parameters for calculating the emission value are obtained from a model that includes the available variables of the engine, the year of the first registration of a particular vehicle type and the square root relationship between the engine and the emissions. By confronting the model that includes the frequency of registration of individual vehicle makes with a model that does not include the frequency, it was discovered that the latter model provides considerably better results, especially with diesel engines. The advantage of leaving out the equations of which the results were influenced by the market and distorted by calculating the operating costs of vehicles according to different categories is the possibility of universal application in foreign markets, not only in the Czech Republic, which

Table 6 Results of the regression to estimate CO₂ based on the engine capacity and year of vehicle registration without the frequency

	Gasoline engines		Diesel engines	
	R = 0.934 R ² = 0.872		R = 0.867 R ² = 0.752	
	b	std. error of b	b	std. error of b
Constant	6729.485	242.658	3816.232	386.659
Year	-3.378	0.121	-1.957	0.193
$\sqrt{\text{Engine capacity}}$	5.547	0.047	6.269	0.117

is in line with Ramanathan and Feng (2009), who recommend a global solution to the emission issue.

The key result of our research is the formulation of an equation for quantifying the emissions of old vehicles with petrol engines and old vehicles with diesel engines. By following the above-mentioned procedures, it is possible to explain 87% of the emission values with petrol engines and 75% with diesel engines.

Our estimates quite accurately describe the production of emissions of vehicles registered since 2000. Nevertheless, for now, we cannot vouch for the accuracy of these estimates in the case of older vehicles. We can only assume that the estimates of emission values will be more accurate in the case of older vehicles registered closer to 2000 than in the case of very old vehicles. It is therefore necessary to test and refine the presented model further for the determination of emission values of older vehicles as a possible environmental road tax base. Furthermore, Franco et al. (2013) mention that even then the real emissions may differ from the declared (let us also include calculated) levels, for example due to the variability of drivers' behaviour or traffic situations, and they recommend subsequent verification of the measurements of emission levels.

Despite the mentioned shortcomings, it is clear that the stated second-best approach system first eliminates the duality of the road tax base currently applied in many countries (e.g. Murray, 2011) resulting from different taxation of older vehicles from newer vehicles and second does not contain injustice and distorting degrees in the tax base. Next it brings the necessary environmental aspect to the tax base, corresponding to the justified requirement in the taxation of vehicles. The importance of this form of road tax is also enhanced by Blanc and Derkenne's (2010) detection of emission reduction if the environmental aspect is included in the tax burden.

References

- ADAMEC, V. (2005). Vliv emisí pevných částic z dopravy na zdraví obyvatel. *Doprava* 47(5): 11–13.
- ANDRLÍK, B. (2013). Road tax in the Czech Republic during the period 1993–2011. *Acta Oeconomica et Informatica* 16(1): 51–55.
<http://dx.doi.org/10.15414/raae.2013.16.01.51-55>
- AUERBACH, A., FELDSTEIN, M. (2002). *Handbook of Public Economics* 3: 1347–1421 Amsterdam: North-Holland Elsevier. [http://dx.doi.org/10.1016/S1573-4420\(02\)80025-8](http://dx.doi.org/10.1016/S1573-4420(02)80025-8), [http://dx.doi.org/10.1016/S1573-4420\(02\)80023-4](http://dx.doi.org/10.1016/S1573-4420(02)80023-4)
- BORGER, B., MAYERS, I. (2007). Optimal taxation of car ownership, car use and public transport. *European Economic Review* 51(5): 1117–1204.
<http://dx.doi.org/10.1016/j.euroecorev.2006.08.004>
- CNOSSEN, S. (2005). *Theory and Practice of Excise Taxation: Smoking, Drinking, Gambling, Polluting, and Driving*. Oxford: Oxford University Press.
<http://dx.doi.org/10.1093/0199278598.001.0001>
- DAVID, P. (2012). Principles of taxation of road motor vehicles and their possibilities of application. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 60(2): 483–492.
<http://dx.doi.org/10.11118/actaun201260020483>
- DAVID, P. (2012a). Perspektivy zdaňování motorových vozidel v zemích Evropské unie. In: *Teoretické a praktické aspekty veřejných financí*. 1–6.
- ENGLAND, R. W., CARLSON, R. E. (2008). Motor fuel taxation and regional development: Economic, environmental, and legal aspects. In: Chalifour, N. J. et al.: *Critical Issues in Environmental Taxation*. New York: Oxford University Press, 351–368.
- FRANCO, V. et al. (2013). Road vehicle emission factors development: A review. *Atmospheric Environment* 70: 84–97.
<http://dx.doi.org/10.1016/j.atmosenv.2013.01.006>
- HOLMAN, R. et al. (1999). *Dějiny ekonomického myšlení*. Praha: C. H. Beck.
- JOHANSSON, C., BURMAN, L., FORSBERG, B. (2009). The effects of congestions tax on air quality and health. *Atmospheric Environment* 43(31): 4843–4854.
<http://dx.doi.org/10.1016/j.atmosenv.2008.09.015>
- PROOST, S. et al. (2009). Will a radical transport pricing reform jeopardize the ambitious EU climate change objectives? *Energy Policy* 37(10): 3863–3871.
<http://dx.doi.org/10.1016/j.enpol.2009.07.023>
- RAMANATHAN, V., FENG, Y. (2009). Air pollution, greenhouse gases and climate change: Global and regional perspectives. *Atmospheric Environment* 43(1): 37–50.
<http://dx.doi.org/10.1016/j.atmosenv.2008.09.063>
- SANTOS, G. et al. (2010). Externalities and economic policies in road transport. *Research in Transportation Economics* 28(1): 2–45.
<http://dx.doi.org/10.1016/j.retrec.2009.11.002>
- SERGEANT, N. et al. (2008). The influence of potential policy measures on the eco-efficiency of personal vehicle mobility in Brussels. *WIT Transactions on the Built Environment* 101(1): 291–300. <http://dx.doi.org/10.2495/UT080291>
- SINGER, B. C., HARLEY, R. A. (1996). A fuel-based motor vehicle emission inventory. *Journal of the Air and Waste* 46(6): 581–593.
<http://dx.doi.org/10.1080/10473289.1996.10467492>

Additional sources

BLANC, N., DERKENNE, C. (2010). *The Complementary use of Qualitative and Quantitative Methods in the Assessment of Public Policies*. [Online], accessed at 14. 06. 2015. Available at: <<http://www.iepec.org/paris2010/BlancPresentation.pdf>>.

CZECH REPUBLIC (1993). Zákon č. 16/1993 Sb., o dani silniční, ve znění pozdějších předpisů. *Daňové zákony 2015*: 110–116.

EUROPEAN COMMISSION (1997). *Kyoto Protocol on Climate Change*. [Online], accessed at 01. 06. 2015. Available at: <http://europa.eu/legislation_summaries/environment/tackling_climate_change/l28060_cs.htm>.

EUROPEAN COMMISSION (2005). *Directive Proposal COM/2005/261*. [Online], accessed at 01. 06. 2015. Available at: <<http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1427966703238&uri=CELEX:52005PC0261>>.

HM TREASURY (1998). *Consultation on Reform of Vehicle Excise Duty to Ensure a Cleaner Environment*. [Online], accessed at 31. 08. 2015. Available at: <<http://archive.treasury.gov.uk/pub/html/prebudgetNo v98/vedcon.pdf>>.

LOW CARBON VEHICLE PARTNERSHIP (2011). *Number of low Carbon Cars Sold in the UK*. [Online], accessed at 31. 08. 2015. Available at: <<http://www.lowcvp.org.uk/news/1613/searchresults/>>.

MINISTRY OF INTERIOR (2012). *Centrální registr vozidel*. [Online]. accessed at 24. 03. 2015. Available at: <<http://www.mvcr.cz/clanek/centralni-registr-vozidel-865510.aspx?q=Y2hudW09NA%3d%3d>>.

MINISTRY OF TRANSPORT (2011). *Ročenka dopravy 2010* [Online], accessed at 24. 03. 2015. Available at: <https://www.sydos.cz/cs/rocenka-2010/rocenka/htm_cz/index.html>.

MURRAY, J. (2011). *Car CO₂ Taxation and its Impact on the British Car Fleet*. [Online.], accessed at 28. 03. 2015. Available at: <[http://www.lowcvp.org.uk/assets/presentations/Car%20CO₂%20tax%20in%20the%20UK%202011%20-%20Jonathan%20Murray.pdf](http://www.lowcvp.org.uk/assets/presentations/Car%20CO2%20tax%20in%20the%20UK%202011%20-%20Jonathan%20Murray.pdf)>.

USEPA (U.S. ENVIRONMENTAL PROTECTION AGENCY) (2005). *Emission Facts: Average Carbon Dioxide Emissions Resulting from Gasoline and Diesel Fuel*. [Online], accessed at 24. 03. 2015. Available at: <<http://www.chargepoint.com/pdfs/420f05001.pdf>>.

VCA (2012). *Car fuel Data, CO₂ and Vehicle Tax Tools*. [Online], accessed at 28. 03. 2015. Available at: <<http://carfueldata.direct.gov.uk/downloads/default.aspx>>.

